An economic research agenda for valuing the ORWRP wetlands

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Introduction

Numerous studies have attempted to measure the diverse benefits of wetlands through various economic measures (Bergstrom et al., 2001; Van den Bergh, 2001; Costanza et al., 1997). Few, however, have specifically looked at wetlands' economic nitrogen abatement function (Gren, 1994; Gren et al., 1995). Once viewed as a "waste of valuable land, that could only be improved through drainage and destruction," wetlands are now considered to be multifunctional ecosystems that provide protection from phenomena including climate change, noise pollution and nonpoint source pollution runoff (Mitsch and Gosselink, 2000). Woodward and Wui (2001) attempted to examine relative values of various wetland services through a metaanalysis of 39 replacement cost and contingent valuation wetland studies. Ten attributes were evaluated, and although abatment of nitrogen pollution was not specifically mentioned, the variable "quality" included recharge of groundwater, water control and retention, and the removal and transformation of nutrients. Their upper bound of $1,378 per acre of wetland with a 90% CF for Quality ranked fifth behind commercial fishing ($5,618), storm protection ($5,142), bird watching ($2,782), quantity of water available ($2,571) and flood control ($1,747), finishing just ahead of recreational fishing ($1,342).

This is an important discovery. As Turner et al. (2003b) point out, the ability to value nature's services is constrained by the complexity of nature itself. So many of a wetland's benefits accrue unknowingly to society at large, or to individuals other than the wetland owners. Thus, private owners tend to omit these social costs in their bid rent function of the land, finding it much more profitable to convert the wetland to other uses, at a large cost to society (ERS, 1998). The many stakeholders who have competing interests in wetlands often fail to fully account for the values of the jointly produced wetland products. The stakeholder's self-serving interests result in them looking at their own benefit stream, while failing to observe the wetlands Total Economic Value (Turner, 2000).

A case in point involves the nitrogen cycle within the wetland (Crumpton and Phipps, 1994; Nikolaidis et al., 1998, Mitsch and Gosselink, 2000). We know that wetlands have both inflows and outflows of chemicals from the water and the air, but it is the services not observed during these flows that are significant. Chemical interactions, such as decomposition, mineralization, humification, immobilization, nitrification and denitrification all take place within wetlands, all encompass important elements of wetland function, and all are difficult to estimate economically. Bystom et al. (2000) suggest that wetlands are not being optimally utilized for their pollution sink function. Economically speaking, the marginal value product of wetlands' nitrogen abatement function has been neglected in the economic literature, which has led to an inefficient allocation of wetlands or an overabundance of spillover effects for which wetlands will be considered as an alternative nitrogen control strategy (Bystrom, 2000a).

A good first step toward resolution of this valuation dilemma can be made in the context of an experiment examining effects of hydrologic pulsing at the Olentangy River Wetland Research Park (ORWRP). With pumped river water containing a significant concentration of nitrate-nitrogen from agricultural run-off, the experimental wetlands can be manipulated with pulsed and nonpulsed fluxes of this nutrient-laden water (Mitsch et al., 2002). The controlled hydrologic experiments can be executed so that each service the wetland provides can be evaluated and measured. However we are still faced with the task of developing a model to estimate the economic values of the services a wetland provides. To begin we must look at the difficulties others have faced. Turner et al. (2003a), Shortle and Horan (2002), Turner et al. (2003b) and Gren (1995) attempt to categorize those difficulties.

The Economic Research Design

Despite difficulties in measuring wetlands' nitrogen abatement function, we know the pulsing experiments have revealed many things about wetlands. Nitrogen, in essence, is necessary for the proper growth of all living things. However, an abundance of the chemical causes increased water pollution and water treatment costs (Mitsch and Spieles, 2000), eutrophication of waterways and estuaries (Gren, 2005; Mitsch et al., 2001), and increased and uncertain health risks for plants, animals and humans (Wilson et al., 1999; Gallagher and Smith, 1985).

Nitrogen pollution occurs from many sources, two of which are categorized for discharge regulation as point sources, regulated by CWA (PL 92-500), USEPA, and non-point sources, which are regulated by states, WQA of 1987, sec. 319. These nonpoint sources include runoff from agricultural crops, livestock, and urban areas; direct transport to groundwater by leaching; and atmospheric deposition.

This relationship between nitrogen and the environment is classified economically as a negative externality, or simply the transmission beyond the recognized legal boundary of the producer of some quantity of matter that gives rise to costs for others (Desgupta and Pearce, 1979). These effects are called externalities precisely because the impact on others are external to the unit that makes the decisions about the resource's allocation (Bromley, 1997). Hitzhusen (2001) depicts the externality with familiar supply and demand curves, where price is on the vertical axis and the joint production of goods and bads along the horizontal axis (Figure 1).

Currently, the cost of nitrogen pollution is borne by society, meaning all of us pay in some way through reduced water quality, health risks, and degradation of natural areas and waterways for future generations. Both agricultural best management practices (BMPs) and economic policy mechanisms have been created in an attempt to combat this externality. Horan and Shortle (2001) analyze the effects of the economic policy mechanisms for the control of nonpoint source nitrogen pollution. Their analysis includes taxes and subsidies, which include charges on purchases of nitrogen fertilizer, governmental standards, which places restrictions on nitrogen applications and their timing, regulations on applications in excess of crop needs, mandatory pollution controls, markets, such as nitrogen trading programs, changes in property rights, contracts and bonds, such as land retirement and conservation contracts, conservation and wetland reserve programs, incentives to uise BMPs and precision farming, and liability measures which use strict liability and negligence. Doering et al. (1999) also present a thorough analysis of the drivers that seemed most responsible for meeting a nitrogen loss pollution constraint, and present both benefits and costs from the consideration of many different stakeholders, including nitrogen producers, users, emitters, and victims using the EPIC model.

Although neither study found one specific strategy that outperformed any of the others, Horan and Shortle (2001) make some very revealing statements in their analysis. Under their framework there are three broad questions economists must be concerned with before seeking a nitrogen pollution control instrument: who to target, what pollution compliance measures should be used, and how best to induce changes. They state that analysts should focus only on those most likely to emit nitrogen; which would be the large number of small contributors (farmers), and that environmental solutions are

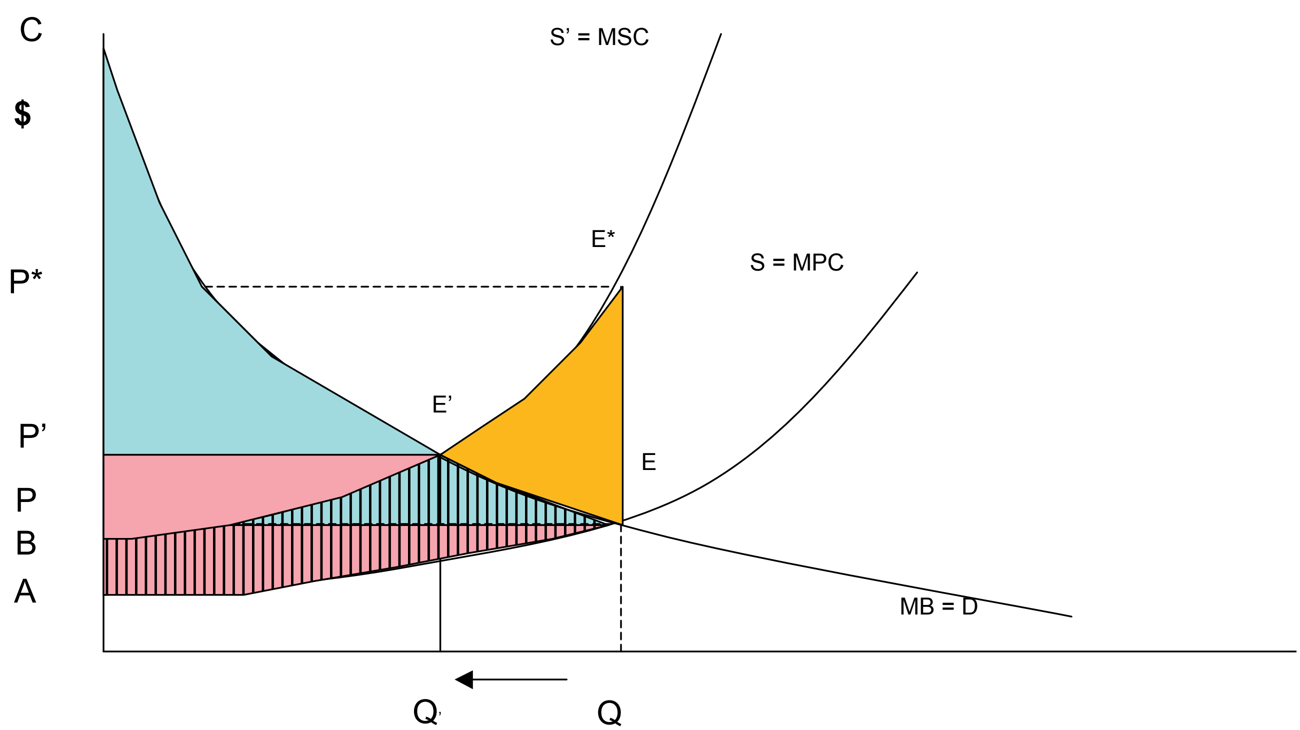

Figure 1 (Hitzhusen, 2001). D = marginal benefit to farmers, S= marginal private costs of farmers, S' = marginal social costs, Q = joint output (goods and bads), E = equilibrium before cost internalization, E' new equilibrium after tax or regulatory standard, P' = new price, P'E'C = consumer surplus, P'E'B = producer Surplus, EE'E* = Dead Weight Loss and a Potential Pareto Improvement exists = if NMB > NMC ≈ E*E'E + P'E'C + P'E'B > PEC + PEA. E* and P* can be considered as the surplus chemicals and soil erosion which imposes costs on downstream users, and E'Q' could be considered a critical threshold; any production of bads over this equilibrium would exceed environmental assimilative capacities. As production moves from Q to Q' due to a reduction in production, the excess costs are internalized, meaning the cost of pollution to society is now treated as a cost of production to the producer.

most optimal. They also found that a second-best tax for a pollution-decreasing input will be positive if an increase in the use of the input is associated with increased demand for the use of the pollution-increasing input, resulting in increased environmental consequences.

The Topic 6 Report came to this same conclusion, echoing Shortle and Horan, in that a mixed policy using several different nitrogen control strategies may be the most cost-effective approach when there is a great deal of variation in the physical, ecological and economic conditions present. This reinforces the concept of using wetlands as a nitrogen pollution decreasing input. It now becomes a question of property rights, a safe minimum standard and economic models.

Property Rights

To discuss property rights, we must first begin with the Coase Theorem and the theory behind property rights. Land ownership consists of a "bundle of rights." (Heimlich, 1998) These rights are well protected by governments except in matters of eminent domain and public safety in which governments can take property for public use with compensation or to prevent harm to others by actions occurring on the land.

The Coase Theorem states that when property rights are implicitly assigned to the producers of the bads (emissions), or in our case the farmers, and if there is no regulation over the externality producing activity (nitrogen applications), the emitters (farmers) will drive the marginal benefit of the "free" nitrogen emission to zero. The producers of these emissions are allowed to dispose of their wastes for free, causing society and the environment to either pay for cleaning or to pay the producers to pollute less.

However, when property rights are implicitly assigned to the consumers, or to the users of water downstream, a high amount of regulation of the externality producing activity will exist. Simply stated, consumers have the right to clean water. The producers of these emissions would then have to pay the group who owns the property right an amount equal to the damage they will cause by emitting. Coase stated that in the absence of government (or standards), both consumers and producers should take averting action (private bargaining) to maximize the value of the spillover to both receivers and producers of the externality. However, Coase was referring to one producer and one receiver. Zeckhauser and Fisher (1995) generalize this outcome to the case of non-point source pollution where there are many producers and consumers.

Without well-defined property rights that are: comprehensively assigned, exclusive, transferable and secure; incomplete markets exist. With incomplete markets, no incentive exists to change from the status quo. The inability or unwillingness of governments to assign property rights to cover each and every environmental transaction or contingency, will not allow resources, such as wetlands, to move to their highest valued use. The four types of property rights discussed in the literature include: State, Private, Common and Open Access. (Bromely, 1997)

Economics flows from the assignment of these property rights. Without property rights, there can be no benefit stream and thus no measurable benefits to value. The same is true for wetlands. As we stated previously, without well-defined and well-assigned property rights, natural resources fail to move to their highest-value use. Presently, nitrogen emissions place a cost on society from the market failure of an externality steming from an incorrectly assigned property right. By changing the familiar property regime for environmental resources from a private to a more common property regime, entitlements over the distribution of net economic surplus would accrue to a more inclusive group of stakeholders. The value of the benefit stream will rise, in turn causing the value of wetland services to rise.

Methods

But, how do we value these services through an economic market? The methods that exist to value wetland functions are too numerous to mention here, but a meta-analysis, a replacement cost analysis, an uncertainty analysis through a regulatory constraint or safe minimum standard, and existing market and nonmarket values were all considered. The methods that were ultimately selected to value the Olentangy River Wetland Research Park wetlands nitrogen abatement function consist of: (1) developing a benefit-cost analysis framework to analyze strategies in estimating a value as a marginal reduction in nitrogen emissions; (2) measureing the increase in treatment costs of the City of Columbus, Division of Water, water treatment plant after a N advisory and then yearly in anticipation and prevention of a N advisory using existing market data; (3) performing an Aversive Behavior/Defensive Measure analysis through a Columbus, Ohio household consumption function that will examine the changes in purchases of bulk packaged water sales data as a measure of willingness to pay, and (4) developing a framework analysis for the wetlands value in decreasing the risk and uncertainty of a wetland as a nitrogen pollution control policy. Through these methods, we will attempt to place an economic lower-bound value on the ORWRP's two, 1-acre experimental wetlands.

The Models

Model 1

Our first model develops a benefit-cost analysis framework to analyze strategies in estimating an economic value as a marginal reduction in nitrogen emissions. This first model consists of a Benefit-Cost Analysis or the Net Present Value of [Nitrogen] Control Strategies (Hitzhusen et al., 1984):

$$NPVs = \sum_{y=1}^{Y}\sum_{t=1}^{T}\sum_{i=1}^{I}\frac{Bsyti}{(1+r)^t} - \sum_{y=1}^{Y}\sum_{t=1}^{T}\sum_{i=1}^{I}\frac{Osyti}{(1+r)^t} + Ksyi$$

where, Y = income, T = time, K = initial capital outlay, r = discount rate (see Hitzhusen and Gutrich, 2004), s = strategy, I = categories of benefits and costs associated the alternative nitrogen control strategies, B = annual benefits of alternative nitrogen control strategies, and O = annual costs of alternative nitrogen control strategies.

These alternative nitrogen control strategies include utilizing wetlands, increased water testing, bottled water purchases, installation of treatment equipment; both residentially and municipally, finding a new water source, tolerating it, or moving away. (Bayoh et al., 2002) Estimation of the private and social costs through a benefit-cost analysis of the nitrogen control strategies will allow the researcher to conceptualize the impact of the nitrogen nonpoint sources pollution problem and allow a more controllable undertaking of the impacts and issues involved.

Model 2

Our second model evolved from our discussions with the City of Columbus, Division of Water's Quality Assurance Lab at the Dublin Road Water Treatment Plant and the Plant's Operations Manager. We were able to obtain nitrogen data on their monthly "finished water" samples for their nitrogen maximums for the years spanning 1983 to 2003; historical data from the labs database of USGS testing data for 6 field stations along the Scioto River from the Hoskins Road testing station, Lat. 40.4194, Long. -83.09685, to the raw water intake to the Dublin Road Water Treatment Plant. We were also able to acquire cost data from 2001 to the present, for dollar value per million gallons of High Service or Finished Water and dollar value per million gallons of Low Service or Raw Water.

We plan to measure the increases in treatment costs of the City of Columbus, Division of Water, Water Treatment Plant after a nitrogen advisory and then yearly in anticipation and prevention of a nitrogen advisory, from 2000 to our modeled year 2002. We will use a cost function and measure the increase in costs during the time periods when a nitrogen spike would be most likely to occur.

Model 3

The NOAA Topic 6 Report (Doering, 1999) states two ways to utilize economic market data in the valuation of ecological functions provided by wetlands. They are the replacement cost method and the avoided cost method. The replacement cost method seeks to price the service in equivalent man-made services, such as nutrient filtering. (Breaux, et al, 1995, Bystrom, 2000, Gren 1995) The avoided-cost method seeks to find a value of the service by using the value of items purchased so as to keep their same level of utility and avoid the damages from the pollution they would knowledgeably be exposed to.

Our third model seeks to perform an Aversive Behavior/ Defensive Measure analysis. Courant and Porter, 1981, first examined the relationship between willingness to pay for environmental quality and external diseconomies by examining the household utility function. Hartford 1984, stated theoretically that the individual maximizes utility over cleanliness and a general commodity, trying to assess individual risk and their changes in consumption behavior. Consider a utility function depicting an individual's private consumption of a level of cleanliness (or clean water) and their normal bundle of goods:

$$\max U = U(X, C) s.t. Y = X + qF$$

Where U = utility of consumer, X = numeraire basket of goods. and C = function of C(F,W) or the level of water cleanliness. This utility function is constrained by a spending budget, in which Y = Income, q = q(F,W), which is the cost of a pollution episode, F = frequency of the pollution episode, and W = ambient level of pollution.

In the case of the ORWRP wetlands, avoidance cost will allow the researcher to analyze and measure this utility function through a Columbus, Ohio household consumption function. This will examine the changes in purchases of bulk packaged water sales as a measure of willingness to pay during the time of a nitrogen advisory or in anticipation of a nitrogen advisory. Our sample of weekly bulk packaged water data is drawn from Columbus, Ohio metropolitan area stores from a national supermarket chain. Due to data constraints we will analyze the year 2002, even though no nitrogen advisories were in affect during that time. We will attempt to identify key variables to determine a bulk packaged water demand function from the bulk packaged water sales data for 2002. This will allow us to estimate a residual willingness to pay for an alternative source of drinking water that may be lingering for consumers after experiencing a six-week nitrogen advisory occurring in a portion of Columbus from June 13, 2000 to July 5, 2000 where it was unsafe to consume and best to avoid the unsafe nitrogen laden water from their tap. (Harford, 1984, Bartik, 1988, and Abdalla, et al, 1992; EPA, 2000).

Horan and Shortle (2001) state that there are two special circumstances where extensive information on demand for, and supply of a good are not required. The first is when water quality is a perfect substitute for the purchased input and the second is when the change in total costs does not affect marginal cost and output of the good. "The cost saving implies a true measure of the benefits of the change in quality (Freeman, 1979b)." Examples would be the avoided cost function of bulk packaged water sales, or a reduction in chemicals needed to treat water for drinking as more and more nitrogen control strategies (wetlands) are implemented strategically throughout a region, respectively.

Model 4

Bystrom et al. (2000) present the concept of nitrogen abatement uncertainty into the pollution control constraint, PC*. They address an overall uncertainty of pollution abatement capacity and impacts of point source and nonpoint source pollution and their stochastic nature. Their model presents probability as it enters the cost equation. This causes the efficient proportion of spending to dispose of wastes to not be at its most cost efficient allocation. The use of Waste Water Treatment Plant (WWTP) and wetland substitutability becomes questionable and an inefficient allocation of wetland and WWTP abatement is attained.

Their model considers a watershed with two sources of nitrogen emissions: agricultural or NPS pollution and a WWTP or point source pollution. There are also two methods for controlling the nitrogen pollution: construction of wetlands and further investment in Waste Water Treatment Plant. The authors use a chance constrained programming approach which has been commonly applied for solving economic programming problems under uncertainty and is useful for illustrating the impact of uncertainty and how the variance of emissions affect the optimal solution.

Their Pollution Constraint formula is as follows:

$$E(P_L) + \phi_\alpha V(P_L)^{1/2} \leq PC^*$$

where $E(P_L)$ = expected nitrogen load,

$V(P_L) = V(R) + V(Q) - 2\mathrm{Cov}(Q,R)$ = variance of total nitrogen load, and

ϕ_α = parameter specifying the weight that should be attached to the variance of emissions in order for the abatement target or the pollution constraint amount, PC*, to be reached with a probability of α .

Since *V(PL)* is assumed to follow a normal distribution, the value of ϕ_α is obtained from the standard normal cumulative distribution. If uncertainty of emissions is irrelevant to the problem, then ϕ_α is equal to zero or the probability of reducing nitrogen emissions solely on expected emissions is zero and would have no effect on the pollution constraint equation. Through the pulsing experiments at the ORWRP wetlands, we see that uncertainty is relevant to the problem of nitrogen emissions.

Breaux et al. (1995) have also examined uncertainty while measuring a natural wetland system as a substitute for traditional waste water treatment. Gallagher and Smith (1985) initially analyzed uncertainty while attempting to measure environmental valuation changes and found that the amenities were not certain and if households recognized this uncertainty in the amenities they were selecting, the conventional approaches to benefit measurement were inappropriate. Turner et al.1(1995) have also viewed wetlands as an insurance policy for farmers against any liability they may face from causing nitrogen pollution.

This analysis of uncertainty could also lead to an analysis of nitrogen control strategies through minimum risk variance portfolio theory where nitrogen pollution control instruments can be evaluated as portfolios of minimum risk on the portfolio possibility set assuming E-V preferences.

FIgure 2 illustrates the existence of uncertainty for residents in Columbus, Ohio for nitrogen nonpoint source pollution, indicating that more studies will need to be performed before an accurate economic estimate can be included as a sub-model and placed in the wetland hydrological and biochemical model.

Results

The empirical results of Models 2 and 3 are presented in a recently coumpleted MS thesis at OSU by Tenwalde (2004). In this paper, we have attempted to put forth a research agenda for the valuation of nitrogen nonpoint source pollution absorbed by the ORWRP. These economic models attempt to estimate the value of the ORWRP wetlands for its nitrogen nonpoint pollution abatement function. Once many of these public sector service functions of a wetland are realized (Costanza et al., 1997), the analysis of the functions of a wetlands becomes more easily done and understood. (Doering et al,, 1999)

Conclusions

Our conclusions, thus far, are that the pulsing project taking place at the ORWRP is highly relevant to many harmful and uncertain problems that ecosystems across the globe are facing. Future research done at the ORWRP is essential if the knowledge on the reliability of wetlands to retain nitrogen from agricultural runoff is desired. Our dependence upon wetlands is becoming more and more clear through these experiments. More patterns of dependence will undoubtedly emerge, hopefully before many more natural wetlands are lost and anymore mitigated and treatment wetlands are built. (Doering et al., 1999, Mitsch et al., 2001)

On our attempt at determining a model for valuation of the nitrogen abatement function of wetlands, it seems to us and others (Zeckhauser and Fisher, 1995; Turner et al., 1995; Shortle and Abler, 2001) that any approach to valuation should be thought of as an incomplete and uncertain venture. Therefore, a determined effort should be directed towards different types of procedures for assessing an economic or willingness to pay value.

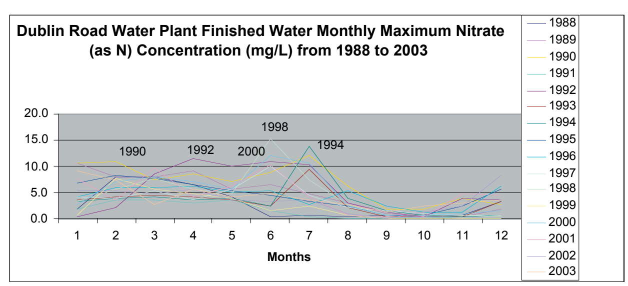

Figure 2. Maximum monthly NO_3-N in finished water from Dublin Road water plant. Source: City of Columbus, Division of Water, Water Quality Assurance Lab.

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